MARICOPA ASSOCIATION of GOVERNMENTS

MAG ITS Strategic Plan Update

Technical Memorandum #6A

- Operational and Implementation Strategies

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1. INTRODUCTION AND BACKGROUND

Technical Memorandum No.6A summarizes the efforts of Task 9 of the *MAG ITS Strategic Plan Update*. The implementation and operation of ITS technologies differs greatly from the deployment of more traditional types of transportation infrastructure such as adding roadway capacity. The implementation and operation of ITS often requires regional, multi-jurisdictional coordination at an increased level compared to traditional infrastructure. A coordinated approach to ITS planning and deployment provides opportunities for significant interoperability efficiencies, and ensures that systems in various jurisdictions do not conflict. ITS deployments also require an increased focus on operational planning to a much greater degree than planning for traditional infrastructure improvements. This increased operational focus is necessary to provide for the continued maintenance and operation of the systems as they were intended.

The Regional Architecture, detailed in Technical Memorandum No. 5, provides the first step towards a coordinated regional ITS infrastructure. This technical memorandum explores issues that will further promote regional collaboration for the efficient planning, implementation, and operations and maintenance (O&M) of ITS in the MAG region. The operational and implementation strategies presented in this memorandum were developed to fulfill the following objectives:

- Identify opportunities for enhancing regional collaboration in implementing and operating ITS deployments;
- Recommend procedures for addressing multi-jurisdictional issues;
- Estimate the cost and resource requirements of ITS elements to be included in the plan;
- Identify potential funding sources; and
- Identify potential private sector participation opportunities that may promote the efficient implementation and operation of ITS in the MAG region.

2. OPPORTUNITIES FOR REGIONAL COLLABORATION

The coordination between MAG member agencies in the deployment of ITS in the greater Phoenix region is one of the better examples of regional collaboration in the nation today. Through the AZTech Model Deployment Initiative (MDI) and current, ongoing MAG activities, the regional agencies have established communication links and decision-making procedures that help to promote a coordinated approach to developing the region's ITS infrastructure and services. This history of multi-jurisdictional collaboration forms a strong foundation for further enhancing regional coordination and cooperation.

Table 1 presents some of the systems currently deployed or planned in the MAG region, and identifies the agency or group of agencies *typically* responsible for various activities. The table shows that several relevant examples of current multi-jurisdictional collaboration can be found in the region, (e.g., multi-agency coordination on the Smart Corridors implementation and operation) and many additional potential situations exist for increased collaboration.

Table 1 – Agency System Responsibilities

System	Planning	Implement	Operations	Maintenance
Freeway Management System	MAG/ADOT	ADOT	ADOT	ADOT
Freeway Service Patrol	MAG/DPS/ ADOT	MAG/DPS/ ADOT	DPS	DPS
Highway Closure and Restriction System	ADOT	ADOT	ADOT	ADOT
ALERT – Incident Response	ADOT	ADOT	ADOT	ADOT
REACT – Incident Response	MCDOT	MCDOT	MCDOT	MCDOT
Smart Corridors	MAG	AZTech/Local	Local	Local
Parking Management	Local	Local	Local	Local
Central Signal Control Systems	MAG/Local	Local	Local	Local
Transit Systems	RPTA/Local	RPTA/Local	RPTA/Local	RPTA/Local
Traffic Management Centers	MAG/Local	AZTech/Local	AZTech/Local	AZTech/Local
TMC Information Sharing	MAG	AZTech/Local	AZTech/Local	AZTech/Local
azfms.com Website	ADOT	ADOT	ADOT	ADOT
Additional Traveler Information Systems	MAG/AZTech/ Private	AZTech/ Private	Private	Private

The following sections identify potential opportunities to build on this foundation and foster improved regional collaboration. Further, **Section 3** of this memorandum presents recommendations for addressing multi-jurisdictional issues that may serve as barriers to seizing these opportunities.

2.1 ITS Strategic Plan Update

This current update of the MAG ITS Strategic Plan provides one of the most substantial opportunities to promote regional collaboration. The participation and input of the member agencies is essential to the success of the project and the continued relevance of the plan that is produced. MAG member agencies have contributed greatly to all phases of the development of the MAG ITS Strategic Plan Update. This participation is anticipated to continue throughout the remainder of the plan development and through the future use of the plan. By keeping the plan

current and relevant through periodic review and revision, the plan should continue to serve as a guide for coordinating the regional implementation and operation of ITS.

Once complete, the use of the plan to guide ITS deployment and investment in the region should be encouraged. The MAG ITS Strategic Plan Update should be used as a high-level framework for promoting the coordinated deployment and operation of ITS in the region. ITS plans developed by local jurisdiction and plans for individual ITS deployments or initiatives in the region should be compatible with the ITS Strategic Plan Update and regional architecture. The inclusion of the project in the appropriate plan is also a requirement of several Federal-funding programs (e.g., ITS Integration component of the ITS Deployment Program).

Often times, ITS deployments may be neglected or treated as separate elements in transportation plans focused on traditional infrastructure improvements. A focused effort should be undertaken by MAG member agencies to incorporate the ITS elements identified in the ITS Strategic Plan Update with other relevant plans. This includes the horizontal integration of the plan with regional transportation improvement plans (TIP) and long-range transportation plans. This likewise includes the vertical integration of the plan elements into both statewide and local transportation plans (e.g., TIP, STIP, and long-range plans). The integration with these and other relevant plans, such as capital improvement plans, will help ensure the proper consideration of ITS improvements and help secure stable funding for the operation of the deployments in the region.

2.2 Maintaining Consistency with Regional Architecture

The regional architecture presented in Technical Memorandum No. 5, MAG Regional ITS Architecture, provides a critical mechanism for promoting regional coordination. The architecture details linkages between different ITS initiatives in the region and represents a balanced approach to ITS deployment and operation (i.e., deployments are properly supported by the appropriate technologies and linkages). Maintaining this balance between ITS deployments is critical to the success of each individual component as well as the regional ITS infrastructure as a whole. The architecture highlights the relationship between the individual components and can be used to demonstrate the impact of the failure of any component or set of components.

It is, therefore, critical that the deployment and operation of ITS in the region remain consistent with the regional architecture. Proposed ITS deployments, or proposed changes to operating procedures for existing ITS deployments, should be routinely compared with the regional architecture for consistency. Non-compatible initiatives should be reviewed to determine the impact on the architecture and modifications incorporated as necessary. The continuing review, evaluation, and revision of the architecture will ensure that the framework remains flexible to accommodate technological and regional changes, and remains relevant as a guide for ITS deployment and operation in the region. The regional consistency with the National Architecture – as provided in the regional architecture – also provides opportunities for securing federal funding to lessen the regional funding burden.

2.3 Shared Operating and Maintenance Agreements

Like most other metropolitan regions, the focus of the MAG member agencies in recent years has primarily been one of planning and implementing ITS elements. Less attention has been paid to the operation and maintenance of existing ITS deployments. As the number of ITS technologies deployed in the region has continued to increase and early ITS equipment has approached obsolescence, agency resources have been stretched to meet the expanding operations and

maintenance needs. Other agencies have been faced with escalating training costs in order to provide their personnel with the skills to properly operate and maintain the new technologies.

The economies of scale possible through sharing some of these operating and maintenance activities across agencies or jurisdictions are substantial. The development of shared operating and maintenance agreements presents a significant opportunity to improve regional collaboration in addressing O&M issues. These sharing agreements allow the better specialization of personnel and provide for more efficient utilization of resources. These agreements also often result in improved standardization of deployments and improved procurement efficiencies.

The co-location of traffic management centers with emergency management dispatch is a unique example of shared operations that are being implemented nationwide. These arrangements can provide both a cost savings to agencies as well as increased functionality. The ability of traffic and emergency management providers to coordinate and share information during an incident is increased due to the location of operators in the same facility. Shared use of building facilities, traffic monitoring and surveillance devices, and communications equipment can lead to a cost savings for all agencies. These types of arrangements should be further considered in the MAG region by agencies developing or upgrading traffic management centers.

2.3.1 Shared Operating Agreements

Shared operating agreements can vary greatly in scope and complexity – from a simple agreement to allow one agency to view another agency's CCTV feed, to complex multi-jurisdictional agreements to operate traffic management centers cooperatively for an entire region. The AZTech Operations Working Group is currently investigating some multi-jurisdictional opportunities including:

- Coordination of traffic signal operation across multiple agencies;
- Sharing of CCTV viewing and control;
- Sharing of VMS use and control; and
- Coordination of incident management responsibilities.

These opportunities should provide significant cross-agency benefits and cost reductions, and should be encouraged and facilitated by the MAG ITS Committee. Multi-agency coordination of operations, such as these opportunities, has provided substantial benefits for agencies and roadway users in other regions where they have been successfully implemented. These joint operational initiatives have recently been recognized for their high potential to provide benefits to agencies and are being evaluated by the FHWA. Several examples of shared operating agreements, and the anticipated benefits are presented below.

- **Silicon Valley Smart Corridor** – A number of Silicon Valley jurisdictions have implemented an agreement to jointly coordinate and operate freeway and arterial ITS components along a 15-mile stretch of the I-880 corridor. Participants in this agreement include: Caltrans, the Santa Clara Valley Transportation Authority, Santa Clara County, and the City of San Jose, and ten additional local and state agencies.

  This sharing agreement provides enhanced information sharing between jurisdictions in the event of freeway incidents and allows the joint operation of CCTV, parallel arterial traffic signals, ramp meters, and VMS to effectively manage diverted traffic during the incident. Specifically, a communication infrastructure has been deployed that allows the San Jose TMC to assume control of an array of multi-agency signals, cameras, and

variable message signs during incident conditions. The various agencies' equipment is operated as a single integrated system until the incident is cleared. Following the incident clearance, control of each agency's signals is passed back to each respective jurisdiction's TMC.

A detailed concept of operations has been approved by all involved agencies to clearly define responsibilities for the different jurisdictions. Anticipated benefits include improved clearance time for diverted traffic, better management of traffic diverted to surface streets during freeway incidents, improved notification of incidents for agency personnel, and lower agency operating costs resulting from decreased staff time required at the multiple-agency traffic management centers.

- **Seattle I-5 Corridor Operational Coordination –** Multiple agencies are coordinating to share information and coordinate traffic management operations along the I-5 corridor in the Seattle region. This coordination includes the joint enhancement of agency-to-agency communications infrastructure and protocols, and shared development and operation of multi-modal traveler information system. Benefits include enhanced traffic management capabilities due to improved information and reduced agency costs due to the sharing of ATIS operations.

- **Twin Cities Orion Project –** The Minnesota DOT (MnDOT) and multiple local and regional agency partners in the Minneapolis/St. Paul region have developed a number of innovative public/public agreements to share in the operations of ITS. These sharing initiatives include the joint operation and coordination of traffic signals and ramp meters, shared incident management operations, coordination of a regional traveler information system, and shared information capabilities with public transit providers.

  MnDOT and their local agency partners have integrated various systems operated by various jurisdictions to develop an integrated corridor traffic management (ICTM) system. For example, during extreme traffic conditions, MnDOT assumes control of local jurisdiction signal systems adjacent to freeway interchanges. The signals and ramp meters are coordinated to operate the freeways and arterials as a single transportation system and promote the rapid reduction in overcapacity conditions. Information is shared between traffic management centers and roadway HAR and variable message signs are coordinated to efficiently direct traffic. Benefits include the improved operational capabilities of the regional ITS infrastructure, reduced agency costs resulting from resource sharing, and the improved standardization of ITS equipment and operating procedures throughout the region.

- **Las Vegas Freeway and Arterial System of Transportation (FAST)**. The Las Vegas FAST will combine the former Las Vegas Area Computer Traffic System (LVACTS) with the new freeway management system, resulting in a shared operations and maintenance agreement for the integrated arterial and freeway traffic management systems. The FAST agreement is based on the existing LVACTS agreement and is currently being developed. Following is a description of the proposed agreement for FAST.

  FAST partners in the agreement include the State of Nevada, City of Las Vegas, City of Henderson, City of North Las Vegas, Clark County, and the Regional Transportation

Commission of Clark County. The purpose is to share the operations and maintenance of traffic management facilities in the Las Vegas area among those agencies involved. All operations of both the freeway and arterial management systems will be located in a single proposed Transportation Management Center (TMC), located in the new Nevada Highway Patrol District Headquarters building. FAST will provide maintenance of traffic management infrastructure including the TMC and communications hardware. Maintenance of field devices can be handled by FAST or by individual agencies if they so desire. It is envisioned that traffic signals will be maintained by each individual agency while CCTV cameras, dynamic message signs, video detection and trailblazer signs will be maintained by FAST.

A proposed Operating Management Committee consisting of one representative from each of the participating agencies will oversee FAST. Each agency will have a single vote on the Operating Management Committee, except the Regional Transportation Commission of Clark County, which is a non-voting member. The FAST executive director will report to the Operating Management Committee and will be responsible for approving any new traffic management infrastructure that is to be operated by the FAST system, selecting the traffic management strategies, and supervising the FAST staff. FAST staff will be employees of the City of Las Vegas, which will serve as the FAST Administrator. The FAST Administrator will serve as the financial agent for the system responsible for collecting and disbursing funds for operation and management of the system.

The proposed funding for FAST is through a "fair-share" formula based on the number of traffic management infrastructure field devices located within each participating agency's jurisdiction that are operated and maintained by FAST. Each agency must contribute the appropriate amount based on the formula, which will be used to operate and maintain the FAST system as well as support the salaries of the FAST executive director and staff. This FAST funding structure is based on the successful LVACTS fair-share formula that has been sustaining the arterial management system for more than a decade.

Although these shared agreements are being increasingly used nationally to operate systems having regional impacts, no common organizational structure has yet emerged. The operating agreements are often developed according to the needs of the individual system or region, rather than by any pre-defined organizational hierarchy or guidelines. For example, according to the operating agreement for the Twin Cities example above, MnDOT provides the lead for operating many of the coordinated ITS components – many which have locations in local jurisdictions. Contrarily, in the state of Idaho it is the local jurisdictions (counties) that operate the ITS components – including ITS components on state highways and interstates. Both these operational models have enjoyed success.

In addition to the multi-jurisdictional operations agreements being considered, there exists several additional opportunities to jointly improve cooperation of the operation of ITS in the MAG region. These opportunities have potential to provide significant efficiencies and include:

- Joint contracting with a private sector provider of ITS operational services (e.g., private sector involvement in providing regional traveler information systems);
- Encouragement of the standardization of operating procedures to improve the opportunities for operational sharing (regional CCTV and VMS agreements);

- Joint training programs to educate personnel from multiple agencies in the operations of new technologies (e.g., NHI incident management training course);
- Shared procurement of ITS equipment to ensure operational compatibility across jurisdictions (e.g., AZTech procurement service);
- Sharing agreements that allow technical personnel from one agency to operate another agency's ITS components on a full-time or situational basis;
- Operations sharing agreements that allow an agency remote access to another agency's traffic management capabilities during periods when the traffic management center is not staffed (e.g., evenings and weekends);
- Allowing one agency to design and/or implement a system that will be operated and maintained by other jurisdictions (e.g., MCDOT design of Smart Corridors);
- Sharing of real-time and archived traffic data for use in operations and planning; and
- Additional public/public partnerships to jointly operate multi-jurisdictional ITS components.

The shared operations agreements being considered represent agreements that would serve to greatly enhance ITS operations and interoperability. These shared operations agreements require careful planning and implementation to ensure the success of the agreement. Failure to cautiously plan these agreements can result in unimplementable or ineffective agreements, or worse, a decrease in interagency cooperation.

Several procedures and strategies are presented in Section 3 that can be used to improve the implementation potential of shared operating agreements. Examples of constructive procedures to follow to promote and support shared ITS operations include the formalization of multi-jurisdictional agreements and the development of detailed operations plans for potential shared ITS deployments.

2.3.2 Shared Maintenance Agreements

Similar to shared operating agreements, agreements to jointly maintain ITS infrastructure have great potential to increase multi-jurisdictional collaboration and provide significant benefits to the involved jurisdictions. The maintenance of ITS components can be a time consuming and resource intensive activity. Combining maintenance and maintenance-related activities across jurisdictions can produce significant benefits for agencies. Examples of shared maintenance activities include:

- Formal public/public agreements to allow one agency to maintain another agency's ITS equipment;
- Multi-agency agreements to provide the sharing of maintenance resources and expertise between agencies;
- Joint training of agency personnel in the maintenance of new technologies;
- Multi-agency purchasing and sharing of specialized maintenance and diagnostic equipment required by ITS deployments;
- Arrangements to combine purchases of replacement ITS equipment in order to lessen the procurement burden and secure volume purchase discounts; and
- Multi-agency agreements to provide for the coordinated planning and scheduling of maintenance activities.

Benefits of these types of shared maintenance agreements include:

- Increased specialization of maintenance staff skills and knowledge;
- Improved upkeep and reliability of ITS equipment;
- Reduced agency costs due to improved efficiency;
- Improved ability to maintain adequate inventory of spare and replacement ITS equipment;
- Improved planning and scheduling of maintenance activities; and
- Reduced liability for individual agencies.

Shared maintenance agreements require careful planning and implementation to ensure the success of the arrangement. The formalization of any agreements and the careful detailing of the agreement in a maintenance plan are examples of procedures that will help contribute to the success of the agreement and help address and multi-jurisdictional coordination issues. These strategies, among others, are discussed in the following section.

3. PROCEDURES FOR MULTI-JURISDICTIONAL ISSUES

The MAG ITS Committee, AZTech MDI and other regional efforts, have effectively promoted the coordinated implementation of ITS on a regional, multi-jurisdictional basis. Over time, these efforts have become the de facto forums for addressing multi-jurisdictional deployment issues that have been encountered. Both formal and informal agreements and communication procedures have been developed between the jurisdictions to deal with deployment issues. Most deployment-related issues that have been encountered have been addressed through these regional committees in an effective manner.

Procedures for addressing multi-jurisdictional issues recommended in this section are primarily focused on improving the resolution of operational and maintenance issues between jurisdictions. The failure to properly address multi-jurisdictional O&M has often proved to be the Achilles heel of ITS deployments in other regions.

Several recommendations are presented below that are intended to promote multi-jurisdictional coordination related to operations and maintenance issues. These recommended procedures include:

- Identification of regional ITS goals for operations;
- Expansion of the regional operations committee;
- Formalization of operating procedures;
- Improved development of operations and maintenance plans; and
- Enhancement of the operational budgeting procedures.

These recommendations are summarized in the following sections.

3.1 Identification of Regional ITS Goals for Operations

An important strategy in promoting regional collaboration and addressing regional issues is the establishment of a regional set of ITS goals for operations. These goals will provide guidance on how ITS will be used to enhance the operations of the regional transportation system. The identification of these goals provides a basis for forming and maintaining sharing agreements between agencies in the region.

These common regional goals require the involvement of a representative group of stakeholders from the region. It is therefore recommended that the MAG ITS Committee take up this issue and attempt to establish some general operating goals for the transportation system in the Greater Phoenix region. These goals and objectives should define how the system in expected to operate in the region and define such issues as:

- Resource Allocation (e.g., identification of procedures and considerations to be used in the allocation of regional resources);
- Facility Priority (e.g., should certain facilities or facility types receive operational priority or should all facilities be treated as part of a single integrated system?); and
- System Expansion (e.g., identification of procedures for integrating regional ITS with other regions.

The clear identification of these goals and objectives would aid in minimizing disruptive multi-jurisdictional issues by providing guidelines for regional system operations. Individual jurisdictions could use these goals and objectives to establish their own long-term operating parameters.

The MAG ITS Committee should initiate discussions on these goals. Agreement among all members is essential to the successful adoption of the regional goals. MAG member agencies should be asked to ratify the goals and objectives individually. These ratified goals would then form the basis for the long-term ITS operation in the MAG region.

It is recommended that MAG identify the regional ITS goals for operations through the development of a regional concept of operations. In the Intelligent Transportation System Architecture and Standards Notice of Proposed Rule Making, filed by the Federal Highway Administration in May 2000, a regional concept of operations is identified and recommended for implementation. However, a definition of the components that should be included in the regional concept of operations has not been developed. The MAG regional concept of operations, in addition to identification of regional ITS goals, could also contain many of the elements described in **Sections 3.2** through **3.5**.

3.2 Expansion of the Regional Operations Committee

The AZTech Traffic Operations Working Group currently operates as the de facto operations committee for many ITS deployments in the region. This group has served a valuable function as the forum for addressing multi-jurisdictional operations issues, and helping to formulate regional operating procedures.

Many deployments, however, fall outside the operational oversight of the AZTech Traffic Operations Working Group. The MAG ITS Committee should encourage the AZTech committee to broaden its focus to a wider set of ITS applications in the region. In this way, the AZTech group could increasingly function as the regional forum for resolving operational and maintenance issues and improving coordination of regional O&M activities. The formalization of a regional operations group would promote the planning of O&M on an equal level with ITS implementation planning in the region, while recognizing the different stakeholders involved in each activity. The working group may also want to consider recruiting additional regional stakeholders to participate in the committee. Potential new members include additional transit representatives, Department of Public Safety, emergency management services, and private-sector organizations such as railroads, commercial vehicle operators, and airport shuttle operators.

3.3 Formalization of Operating Procedures

In the course of implementing the AZTech MDI, many formal interagency agreements have developed between jurisdictions in the MAG region. Likewise, many formal and informal agreements have been developed between the MAG ITS Committee participants to guide and dictate operating procedures. As ITS initiatives are expanded and enhanced in the MAG region, these agreements will gain further importance. Additionally, as new members are initiated into these sharing agreements, the agreed upon procedures must be disseminated to the new participants.

For these reasons, it is important to document the procedures, whenever appropriate, to ensure the common agreement of the terms and formalize the understanding. This formalization of agreements helps to ensure the survivability of the agreements through changes in staff and management. These formal agreements also provide for the consistent and continuing operation of multi-jurisdictional ITS deployments as they were originally intended.

These formal agreements may take the form of memoranda of understanding for relatively minor operational agreements. More complex issues, such as joint operation of ITS deployments by multiple agencies, may require more binding agreements. These may include entering into public/public partnerships or the formation of an operating authority.

Regardless of the format, the agreement should clearly identify the logical operating structure including:

- "who" makes decisions;
- "what" are the decisions to be made;
- "when" are the decisions to be made; and
- "what" are the corresponding courses of actions once a decision has been made.

In ITS operations, situations arise on a day-to-day basis where critical decisions need to be made. A definitive plan for such decision-making will minimize future confusion and overlapping of responsibilities between the different operating agencies. Like all plans and agreements, the multi-jurisdictional procedures should contain provisions for the periodic review and revision of the agreements to ensure they remain relevant to the current operating environment.

3.4 Development of Operations and Maintenance Plans

Ideally, the planning of operations and maintenance activities should be conducted on an equal basis with implementation planning to ensure the long-term viability of ITS deployments. This is particularly true in the case of multi-jurisdictional deployments; however, O&M planning is often neglected or conducted as an afterthought to implementation planning. This is unfortunate as failure to properly plan for the continued operations and maintenance of ITS implementations may result in future funding shortfalls or inadequate resources to properly operate the improvement. It is therefore critical that O&M issues are properly considered when planning multi-agency ITS deployments.

O&M plans are typically developed as part of the design process, but are often insufficiently detailed to provide adequate guidance. A particularly useful strategy in ensuring the proper treatment and consideration of O&M is the encouraged development of *detailed* and *comprehensive* O&M plans for all regional ITS deployments. The MAG ITS committee should encourage that detailed O&M plans are developed in parallel with design plans for any multi-agency deployment. The improved consideration of O&M will help to minimize future multi-

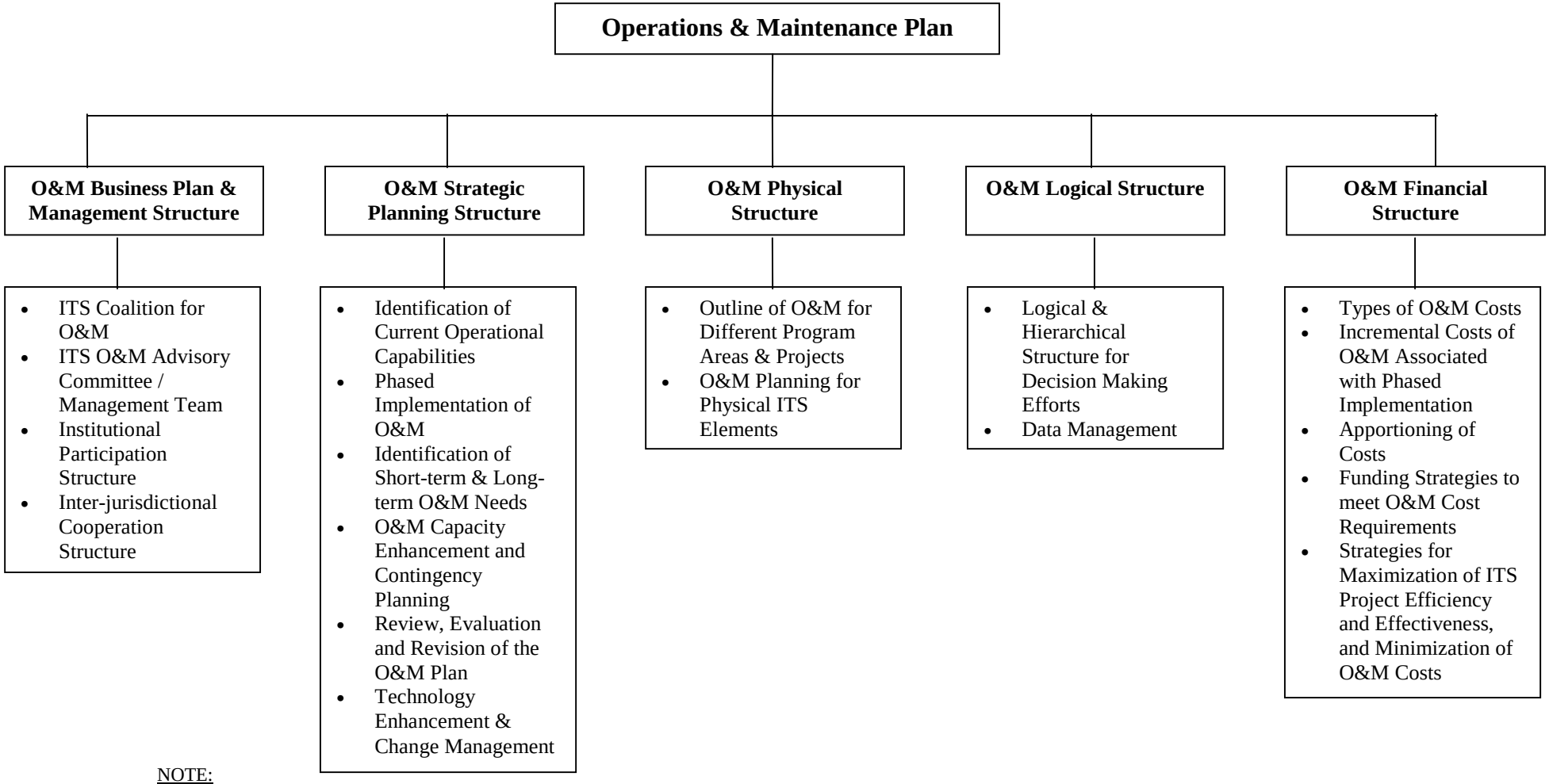
jurisdictional conflicts and ensure that future O&M resources are available to support the deployment.

Ideally, the O&M and design plans (e.g., 60% Plans) for any multi-jurisdictional initiative should be developed jointly with O&M issues driving the scale of the implementation, as well as implementation issues driving the scale of the O&M effort. This requires that the O&M planning effort be established at the early stages of planning for any ITS deployment and be coordinated continually with the design effort. Before developing any multi-jurisdictional O&M plan, each individual jurisdiction involved should first identify their own requirements of the planned system including anticipated uses, performance and reliability needs, available resources, and anticipated O&M contribution to the system. The identified needs and requirements of the individual jurisdictions should then form the basis for negotiating and developing the multi-jurisdictional O&M plan.

These plans should be developed by a coalition of local agencies and designers involved in the ITS implementation and any agencies involved in the long-term operation and maintenance of the deployment, including both public and private agencies. These same agencies should maintain responsibility for reviewing and revising the plans over time to ensure their continued relevance.

Figure 2 provides a sample framework for the development of O&M designed to properly consider the long-term O&M issues associated with ITS implementation. The principle elements of this framework include:

- **Business Plan & Management Structure** – Identifies the management and interjurisdictional cooperation structure;
- **Strategic Planning Structure** – Identifies current O&M capabilities, defines expanded O&M needs paralleling the phased implementation of the improvement, identifies O&M resource and funding shortfalls that may be experienced in future years, and outlines change management plans to overcome these shortfalls;
- **Physical Structure** – Outlines the O&M activities of the implementation (e.g., location, hours of operation, etc.) and provides a detailed inventory of all ITS elements associated with the improvement and all related O&M equipment;
- **Logical Structure** – Identifies the hierarchy for decision making and data management; and
- **Financial Structure** – Identifies O&M costs and cost apportioning among multiple agencies.



NOTE:

- The above organizational chart is a generalized guide to the kind of O&M issues that need to be considered. It is not meant to be a concrete plan or structure. In general, this organizational format will apply to large multi-jurisdictional projects. Smaller projects that involve only one or few jurisdictions need not be given such an extensive treatment.
- ITS projects are different from traditional infrastructure improvement projects in that, O&M are a significant part of ITS projects. The ITS participants in any region need to be prepared for the special O&M requirements of ITS projects, especially those that require coordination between multiple agencies. It is therefore important that the elements shown in this organizational chart are considered as pivotal in the development of an O&M plan for the different ITS projects.

Figure 2 – Framework for an Operations And Maintenance Plan

3.5 Enhancement of the Operational Budgeting Procedures

A critical element of the O&M plans described in the previous section, is the development of detailed financial plans for estimating the costs of operating and maintaining the ITS components. The improved budgeting of future anticipated O&M expenditures is an important strategy for improving multi-jurisdictional collaboration and minimizing future interagency conflicts. The operating plans for any ITS deployment, including single agency as well as multi-jurisdictional initiatives, should be carefully scrutinized to estimate future expenditures related to O&M. Properly anticipating these expenditures helps to ensure the long-term viability of the improvement and minimize the chance of system failure.

There are several key steps to improving the operational budgeting procedure. First, MAG member agencies should identify and estimate future O&M costs for any and all deployments. Traditional budgeting procedures often fail to account for required O&M expenditures or neglect the replacement cost of equipment that must periodically be upgraded. All ITS components should be identified and evaluated to properly forecast any expenditures. MAG member agencies should closely scrutinize these estimates and investigate any suspect assumptions. Project submittals should include these O&M estimates and, if possible, identify sources of O&M support. Estimates of capital and O&M costs associated with various ITS components are provided in **Section 4** of this report. These estimates provide a starting point in improving the identification and consideration of continuing operational costs.

Second, since many ITS deployments are planned as phased implementations, O&M budgets must properly anticipate and provide for the future incremental increase in O&M activities. This is necessary to ensure that future O&M resources are available to meet the expanded needs of ITS components implemented in phases. This is particularly critical in the planning of O&M labor resources. Often, the operations or maintenance tasks associated with an ITS component are added to an existing staff member's responsibilities during the initial stages of deployment. As the implementation incrementally expands, however, the O&M responsibilities may begin to occupy an increasing portion of that staff member's time. Failure to reallocate responsibilities in this situation may result in inadequate time devoted to O&M activities or an inability to meet other responsibilities. MAG member agencies should plot all anticipated future expansions of the system on a timeline. O&M resources should be plotted alongside the phased deployment and compared for gaps in O&M availability. Adjustments should be made to the O&M budget or to the phasing schedule to close this gap.

Third, any O&M budgeting procedures should clearly identify funding responsibilities and the apportioning of costs. This procedure should also include a risk analysis of the funding sources to assess the likelihood of future availability of the funds. For example, MAG member agencies need to identify their reliance on Federal funding mechanisms that may not be re-authorized in future funding legislation. Contingency plans should be identified in such situations ensure the long-term availability of O&M funding.

Finally, any budgeting effort should include an evaluation of the O&M plans to investigate the opportunities for cost sharing and promoting economies of scale. MAG member agencies are encouraged to discuss their O&M plans with other regional jurisdictions to investigate possible O&M sharing agreements. Several types of potential cost sharing opportunities were highlighted in **Section 2**.

Enhancing the operational budgeting procedure has the potential to minimize future interagency conflicts over O&M resources and funding. This strategy also helps to ensure the long-term adequacy of O&M activities that are appropriately phased with planned ITS expansions. The following section provides estimates of costs and resource requirements of various ITS components that may be useful in the budgeting process.

4. COSTS AND RESOURCE REQUIREMENTS

4.1 Staffing Resource Requirements

In order to assess the current and future staffing needs, a survey questionnaire was developed and distributed to member agencies. The purpose of this questionnaire was to obtain a snapshot estimate of the number of agency personnel that were involved with ITS planning and implementation, assess the adequacy of the current staffing levels, and obtain estimates of future staffing needs for regional agencies.

The survey was responded to by nine regional agencies including six local agencies (Chandler, Glendale, Mesa, Peoria, Phoenix, and Tempe) and three state agencies (ADOT, Department of Public Safety, and Arizona State University). Survey respondents were asked to identify current staffing levels in full time equivalents (FTE's) related to several different categories including ITS Planning/Design, ITS Operations, and ITS Maintenance. Responses were expectedly varied depending on each agencies involvement with various ITS activities and ranged from zero to 31 agency staff persons involved with ITS. Averages of the responses are presented in **Table 2**.

Table 2 – Average Current ITS Staffing Levels (in Full Time Equivalents)

	Planning	Operations	Maintenance	TOTAL
Local Agencies	.4	.5	.9	**1.8**
State Agencies	1.3	4.7	5.3	**11.3**
All Respondents	**.7**	**1.9**	**2.4**	**5.0**

Respondents were also asked to identify whether their current staffing levels were sufficient to meet the needs of their agency's systems, more that sufficient to meet their needs, or less than sufficient to meet their needs. Two-thirds of the respondents reported that current staffing levels were *less* than sufficient to meet their ITS needs. The remaining third responded that their staffing levels were sufficient to meet their immediate needs.

Agencies were also asked about their anticipated staffing needs and planned personnel additions. Nearly all (90 percent) of the agencies reported that their plans for future ITS deployments would place greater demands on staff resources. To meet these additional staffing needs, 55 percent of the agencies anticipated adding staff within the next year, while nearly 80 percent anticipated adding staff within the next five years. On average, this anticipated increase amounts to an additional .5 FTE for each agency in the next year and an additional 1.7 FTE's over the next five years. This represents an anticipated staffing increase of 10 percent for the one-year period and 34 percent for the five-year period. If these longer-range staffing needs are realized, ITS staffing levels at the responding agencies will increase by a total of 15 FTE's by 2005.

Based on the responses from regional agencies, increasing staffing levels to meet the increased demands of planned ITS deployments represents a critical strategy that must be pursued to ensure adequate agency capabilities in the future.

4.2 Cost Requirements

Accurately estimating the costs of ITS initiatives can be problematic. Compared to more traditional infrastructure improvements, ITS improvements typically incur a greater proportion of their costs as continuing operations and maintenance (O&M) costs, as opposed to up-front capital costs. ITS equipment also typically has a much shorter anticipated useful life than many traditional improvements, and must be replaced as it reaches obsolescence. Further complicating the ITS cost estimation process is the fact that ITS deployment costs are greatly impacted by the degree in which ITS equipment and resources are shared across different deployments and jurisdictions.

Despite these difficulties, it is critical that planners fully consider and account for the costs of ITS deployments when evaluating and developing deployment and O&M plans. Failure to recognize these costs may result in future funding or resource shortfalls, or worse, the inability to properly operate and maintain deployed ITS improvements. This section of the MAG ITS Strategic Plan Update is intended to assist planners in properly estimating and predicting cost and resource requirements of planned ITS deployments.

The *ITS National Architecture* provides ITS equipment cost estimates intended to guide planners in estimating the costs of various types of improvements. This cost data includes estimates of the average capital cost, O&M cost, and anticipated useful life for hundreds of pieces of equipment and resources needed to deploy and operate ITS improvements. For this study, the ITS Deployment Analysis System (IDAS) software, an ITS planning tool developed by Cambridge Systematics for FHWA, was used to provide an interface to the extensive cost data contained in this documentation. Specifically, the IDAS software tool was used to produce estimates of costs and resource requirements for ITS improvements being planned or considered for deployment in the MAG region. However, when local cost data were available, the local figures supersede the national figures in the presentation of costs.

The costs presented in this section are organized to provide planners with useful information that may be referenced to compare the costs for various deployments in the MAG region. The estimated costs represent average costs that have been experienced and are consistent with the recommended equipment packages detailed in the *ITS National Architecture*. The costs presented in this section are defined as follows:

- **Capital Costs** – Includes those up-front costs necessary to procure and install the ITS equipment. These figures are shown as a total (one-time) expenditure.

- **Operations and Maintenance (O&M) Costs** – Includes those continuing costs necessary to operate and maintain the deployed ITS equipment. While these costs do contain provisions for upkeep and replacement of minor components of the system, they do not contain provisions for wholesale replacement of the equipment when it reaches the end of its useful life. These O&M costs are presented as annual estimates.

- **Annualized Costs** – Represent the average annual expenditure that would be expected in order to deploy the ITS improvement, operate and maintain the ITS improvement, and replace (re-deploy) ITS equipment as it reaches the end of its useful life. Within this cost figure, the capital cost of the equipment is amortized over the anticipated life of each

individual piece of equipment. This annualized figure is added with the reoccurring annual O&M cost to produce the annualized cost figure. This figure is particularly useful to planners in estimating the long-term budgetary impacts of any ITS deployment.

The complexity of ITS deployments warrant that these cost figures be further segmented to ensure their usefulness to planners. Within each of the capital, O&M, and annualized cost estimates, the costs are further disaggregated to show the infrastructure and incremental costs. These are defined as follows[1]:

- **Infrastructure Costs** – Include the basic "backbone" infrastructure equipment necessary to enable the system. For example, in order to deploy a camera (CCTV) surveillance system, certain infrastructure equipment must first be deployed at the traffic management center to support the roadside ITS elements. This may include costs such as computer hardware/software, video monitors, and the labor to operate the system. Once this equipment is in place, however, multiple roadside elements may be integrated and linked to this backbone infrastructure without experiencing significant incremental costs (i.e., the equipment does not need to be re-deployed every time a new camera is added to the system). These infrastructure costs typically include equipment and resources installed at the traffic management center, but may include some shared roadside elements as well.

- **Incremental Costs** – Include the costs necessary to add one additional roadside element to the deployment. For example, the incremental costs for the camera surveillance example include the costs of purchasing and implementing one additional camera. Other deployments may include incremental costs for multiple units. For instance, an emergency vehicle signal priority system would include incremental unit costs for each additional intersection and for each additional emergency vehicle that would be equipped as part of the deployment.

Structuring the cost data in this framework provides the ability to readily scale the cost estimates to the size of potential deployments. Infrastructure costs would be incurred for any new technology deployment. Incremental costs would be multiplied with the appropriate unit (e.g., number of intersections equipped, number of vehicles equipped, number of variable message sign locations, etc.) and added to the infrastructure costs to determine the total estimated cost of the deployment.

Table 3 presents the cost estimates for various ITS components currently planned or under consideration for deployment in the MAG region. Costs are presented for various ITS components including:

- Arterial traffic management systems;
- Freeway traffic management systems;
- Advanced public transportation systems;
- Incident management systems;
- Emergency management systems;
- Regional traveler information systems;
- Commercial vehicle operations; and
- Additional deployments.

[1] The breakdown of infrastructure versus incremental costs was not always available when local cost figures were used. Typically, only the incremental costs are shown for these locally derived component costs.

The capital and O&M costs are shown in **Table 3**, segmented by infrastructure and incremental costs. Capital costs represent the total expenditure while O&M costs are annual estimates. **Table 4** presents the annualized costs, which include capital and O&M as a single annual cost estimate. These costs are shown for various ITS components. A detailed inventory of the ITS equipment associated with each component along with the cost assumptions for each individual piece of equipment is presented as **Appendix A**. These detailed equipment inventories are useful in determining cost allocation and identifying funding responsibilities.

When local cost figures were used in **Tables 2 & 3**, these figures are distinguished in *italics*. Both the local and national cost data for these components are presented in **Appendix A**.

Table 3 – Capital and O&M Cost Estimates for Selected ITS Components

	Capital Costs (Total)		O&M Costs (Annual)	
	Infrastructure[1]	Incremental[2]	Infrastructure[3]	Incremental[4]
Arterial Traffic Management Systems				
Actuated Corridor Signal Coordination	$55,000	$6,250 (per intersection)	$1,100	$350 (per intersection)
Central Control Signal Coordination	$277,500	$7,000 (per intersection)	$543,100	$6,950 (per intersection)
Emergency Vehicle Signal Priority	$–	$8,500 (per intersection) $650 (per vehicle)	$–	$315 (per intersection) $20 (per vehicle)
Transit Vehicle Signal Priority	$–	$8,500 (per intersection) $650 (per vehicle)	$–	$315 (per intersection) $20 (per vehicle)
Arterial Highway Advisory Radio	$127,500	$24,750 (per location)	$106,375	$1,700 (per location)
Arterial Variable Message Sign	*NA*	*$109,000 (per location)*	*NA*	*$3,500 (per location)*
Freeway Management Systems				
Traffic Actuated Ramp Metering	$–	*$15,000 (per ramp)*	$–	*$3,550 (per ramp)*
Traffic Surveillance – CCTV	*NA*	*$17,000 (per CCTV location)*	*NA*	*$2,170 (per CCTV location)*
Traffic Surveillance – Loop Detectors	*NA*	*$9,000 (per location)*	*NA*	*$480 (per location)*

[1] **Infrastructure Capital Costs –** Up front expenditures necessary to implement the basic equipment that enables the operation of the system. For example, the infrastructure capital costs for a variable message sign deployment would include traffic management center hardware, software, and system integration, but would not include the cost of the roadside VMS elements. Once installed, the traffic management center equipment may be used to control multiple VMS.

[2] **Incremental Capital Costs** – Up front expenditures necessary to deploy the roadside components of the ITS system. For the VMS example, the incremental capital costs would include the cost of the roadside sign and the sign standard. These costs are incurred every time an additional VMS is deployed.

[3] **Infrastructure O&M Costs** – The annual expenditures needed to operate and maintain the basic infrastructure equipment.

[4] **Incremental O&M Costs** – The annual expenditures needed to operate and maintain each unit of the roadside equipment.

Table 3 – Capital and O&M Cost Estimates for Selected ITS Components (continued)

	Capital Costs (Total)		O&M Costs (Annual)	
	Infrastructure	**Incremental**	**Infrastructure**	**Incremental**
Highway Advisory Radio	$127,500	$24,750 (per location)	$106,375	$1,700 (per location)
Variable Message Sign	*NA*	*$109,000 (per location)*	*NA*	*$3,500 (per location)*
Advanced Public Transit Systems				
Fixed Route – Automated Scheduling System	$396,500	$600 (per vehicle)	$174,600	$670 (per vehicle)
Fixed Route – Automatic Vehicle Location	$351,500	$1,375 (per vehicle)	$174,600	$1,545 (per vehicle)
Fixed Route – Security System	$598,250	$5,350 (per vehicle) $7,500 (per location)	$230,175	$450 (per vehicle) $6,690 (per location)
Paratransit – Automated Scheduling System	$389,000	$600 (per vehicle)	$174,600	$670 (per vehicle)
Paratransit – Automatic Vehicle Identification	$351,500	$1,375 (per vehicle)	$174,600	$1,545 (per vehicle)
Electronic Transit Fare Payment	$896,500	$2,500 (per vehicle) $43,250 (per station)	$168,100	$1,570 (per vehicle) $8,525 (per station)
Incident Management Systems				
Incident Detection/Verification	$345,500	*$17,000 (per CCTV location)*	$167,275	*$2,170 (per CCTV location)*
Incident Response/Management	$354,250	$–	$229,400	$–
Emergency Management Services				
Emergency Vehicle Control Service	$729,750	$1,150 (per vehicle)	$243,050	$200 (per vehicle)
Emergency Vehicle Automatic Vehicle Location	$133,500	$1,350 (per vehicle)	$105,950	$230 (per vehicle)

Table 3 – Capital and O&M Cost Estimates for Selected ITS Components (continued)

	Capital Costs (Total)		O&M Costs (Annual)	
	Infrastructure	Incremental	Infrastructure	Incremental
Regional Traveler Information Systems				
Telephone-Based Traveler Information System	$1,415,500	$–	$607,900	$–
Web-/Internet-Based Traveler Information System	$1,552,500	$–	$607,900	$–
Kiosk-Based Traveler Information System	$1,552,500	$46,000 (per location)	$607,900	$4,500 (per location)
Commercial Vehicle Operations				
Weigh-in-Motion	$–	$73,000 (per facility)	$–	$3,650 (per facility)
Safety Information Exchange	$300,750	$303,250 (per facility)	$387,550	$6,475 (per facility)
Additional Deployments				
Traffic Management Center	$2.8M - $4.0M	$–	$410K - $500K	$–
Parking Management Systems	527,500	$310,500 (per location)	$126,375	$25,300 (per location)
Railroad Crossing Monitoring System	$120,000	$197,500 (per location)	$52,000	$21,175 (per location)

Table 4 – Annualized Cost Estimates for Selected ITS Components

	Lifecycle Costs (Annual)	
	Infrastructure[1]	**Incremental[2]**
Arterial Traffic Management Systems		
Actuated Corridor Signal Coordination	$3,850	$663 (per intersection)
Central Control Signal Coordination	$590,350	$7,300 (per intersection)
Emergency Vehicle Signal Priority	$–	$1,490 (per intersection) $85 (per vehicle)
Transit Vehicle Signal Priority	$–	$1,490 (per intersection) $85 (per vehicle)
Arterial Highway Advisory Radio	$116,875	$2,938 (per location)
Arterial Variable Message Sign	*NA*	*$10,767 (per location)*
Freeway Management Systems		
Pre-set Ramp Metering	$–	$10,000 (per ramp)
Traffic Actuated Ramp Metering	$–	$14,500 (per ramp)
Central Control Ramp Metering	$296,500	$23,338 (per ramp)
Highway Advisory Radio	$116,875	$2,938 (per location)
Variable Message Sign	*NA*	*$10,767 (per location)*
Advanced Public Transit Systems		
Fixed Route – Automated Scheduling System	$195,925	$730 (per vehicle)
Fixed Route – Automatic Vehicle Location	$193,925	$1,683 (per vehicle)
Fixed Route – Security System	$271,213	$985 (per vehicle) $7,403 (per station)
Paratransit – Automated Scheduling System	$195,175	$730 (per vehicle)
Paratransit – Automatic Vehicle Identification	$193,925	$1,683 (per vehicle)

[1] **Infrastructure Lifecycle Costs** – Annualized expenditures necessary to implement and operate the basic equipment that enables or controls the operation of the system.
[2] **Incremental Lifecycle Costs** – Annualized expenditures necessary to implement and operate each additional unit of the roadside components.

Table 4 – Annualized Cost Estimates for Selected ITS Components (continued)

	Lifecycle Costs (Annual)	
	Infrastructure	**Incremental**
Electronic Transit Fare Payment	$214,425	$1,783 (per vehicle) $9,533 (per station)
Incident Management Systems		
Incident Detection/Verification	$221,375	*$4,599 (per CCTV)*
Incident Response/Management	$261,388	$–
Emergency Management Services		
Emergency Vehicle Control Service	$366,038	$315 (per vehicle)
Emergency Vehicle Automatic Vehicle Location	$118,925	$423 (per vehicle)
Regional Traveler Information Systems		
Telephone-Based Traveler Information System	$709,050	$–
Web-/Internet-Based Traveler Information System	$715,900	$–
Kiosk-Based Traveler Information System	$715,900	$11,071 (per location)
Commercial Vehicle Operations		
Weigh-in-Motion	$–	*$9,367 (per facility)*
Safety Information Exchange	$402,588	$23,388 (per facility)
Additional Deployments		
Traffic Management Center	$633,333	$–
Traffic Surveillance – CCTV	*NA*	*$4,599 (per CCTV)*
Traffic Surveillance – Loop Detectors	NA	*$1,715 (per location)*
Parking Management Systems	$156,875	$42,825 (per location)
Railroad Crossing Monitoring System	$61,000	$33,850 (per location)

It is important to note that these costs represent average cost figures based on the equipment packages recommended in the *ITS National Architecture* except where otherwise noted. Cost figures shown in *italics* were obtained from local cost data. Individual ITS improvements may experience different costs or may require modified equipment inventories than specified here. **Appendix A** describes a methodology for adjusting the cost estimates.

The cost estimates presented in **Table 3** can be used in budgeting and operations planning and for determining future funding levels needed to properly maintain and operate the deployed systems. The capital and O&M costs (combined with the anticipated equipment useful life data in **Appendix A**) can be used to determine capital expenditures necessary to deploy a component, the ongoing expenditures that will be likely realized to operate and maintain the system, and estimates of the timeline for future capital expenditures to replace obsolete equipment. The more detailed equipment information contained in **Appendix A** can be used as a basis for determining cost allocation and O&M funding responsibilities.

The annualized cost figures in **Table 4** are more appropriate for determining the general level of funding that is necessary to ensure the proper deployment and operation of the system over the long term. This annualized cost estimate can also be used in comparison with the anticipated annual benefits of planned ITS components to estimate the economic effectiveness of the deployment. For example, the anticipated annual benefits for any ITS deployment should exceed the annual cost estimate (benefit/cost ratio in excess of 1) for the deployment to be considered a good investment.

5. POTENTIAL FUNDING SOURCES

Accurately forecasting and securing stable funding for ITS has proved difficult in many regions. A recent survey of transportation agencies by the Institute of Transportation Engineers (ITE) revealed an average 20 percent shortfall in funding and resources for traffic control activities by those agencies. As these ITS activities are expanded, the need for deployment and operations funding becomes even more critical. Long-term funding of operations and maintenance activities is of particular concern.

Focusing increased efforts on planning and budgeting O&M costs to accurately predict these costs over the life cycle of proposed deployments is perhaps the best strategy related to the funding of ITS. When the full life-cycle costs of ITS are properly planned and accurately anticipated, the task of finding available funding sources for financing the implementation and operation of the deployment is made infinitely easier.

The requirements for many federal funding opportunities require that ITS is planned consistent with the guidelines provided in the National ITS Architecture. The Transportation Equity Act for the 21st Century (TEA-21) legislation continues eligibility for funding of operating costs for traffic monitoring, management, and control. While continuing to permit annually apportioned Federal-aid funds to be eligible for traffic systems operations and management activities, TEA-21 does not provide separate funding exclusively for system management and operations.[1] Available general funding programs include:

- **National Highway System (NHS) -** Provides for capital and operating costs for traffic monitoring, management, and control facilities and programs. Funds provided on an 80/20 percent federal/local match basis with no time limit for operations.
- **Surface Transportation Program (STP) -** Provides for capital and operating costs for traffic monitoring, management, and control facilities and programs. Funds provided on an 80/20 percent federal/local match basis within the initial project scope.
- **Congestion Mitigation and Air Quality Improvement Program (CMAQ)** - Provides funds for the establishment or operation of traffic monitoring, management, and control facility or program in non-attainment areas. Explicitly includes, as an eligible condition for funding, programs or projects that improve traffic flow. Funds provided for O&M on an 80/20 percent federal/local match basis for 3 years, or longer if the project demonstrates air quality benefits on a continuing basis.

[1] Currently, US DOT rule making has been proposed to better define eligible ITS deployments and enhance the availability of these funding mechanisms for long-term operations financing. The issue is being studied and a Final Rule on eligibility is expected by late 2000.

TEA-21 also authorized several additional Federal funding mechanisms which are available specifically to aid in the deployment and operation of ITS. These funds have been largely apportioned through congressional earmarks and include the following programs:

- **ITS Integration -** This component of the ITS Deployment Program provides funding for activities necessary to integrate ITS infrastructure components that are either deployed (existing) or will be deployed with other sources of funds. This may include the integration of different ITS systems or sub-systems (e.g., freeway management, arterial management, etc.) or the integration of like ITS components across jurisdictions. Eligible activities include the system design and integration, creation of data sharing/archiving capabilities, deployment of components that support integration with systems outside of metropolitan areas, and the development of regional or statewide ITS architectures. Funding for FY2000 was limited to $15 million for a metropolitan area and $35 million for any state. The ITS Integration Program can fund up to 50 percent of an integration project's costs with a minimum of 20 percent of the local match to come from non-federally derived sources.
- **Commercial Vehicle Information Systems and Networks (CVISN) -** This component of the ITS Deployment Program can be used to fund ITS deployments intended to improve the safety and productivity of commercial vehicles and drivers. This program is only available at the state level, however.
- **Corridor Planning and Development and Border Infrastructure (Corridors and Borders) -** This program through the FHWA's Office of Intermodal and Statewide Programs is intended to improve the safety and efficiency of the movement of people and goods through US international Ports of Entry (POE) and along multi-modal trade corridors. Under the National Corridor Planning and Development (NCPD) program, funds are available to states and MPO's for coordinated planning, design, and construction of corridors of national significance, economic growth, and international or interregional trade. Funding is available for up to four years at a maximum 80 percent share of project costs.

A number of additional federal funding opportunities have helped deploy the ITS infrastructure in the MAG region. The Metropolitan Model Deployment Initiative (MMDI) effort provided critical funding for many AZTech-related initiatives. The continuing long-term availability of these ITS-specific funding mechanisms is questionable, however. ITS projects will increasingly be called on to compete for the same construction and operating funding as traditional infrastructure projects. There may be opportunistic situations, however, to secure dedicated funding for specific ITS deployments if and when the funds become available. Periodic inquiries to regional FHWA representatives should be used to identify these potential opportunities.

Beyond federal funding opportunities there are a number of additional funding sources available for some ITS deployments. These include:

- Public/private partnerships [addressed in Section 6];
- Resource sharing with public agencies external to the transportation agency; and
- Revenue opportunities.

Examples of public agency resource sharing include cost sharing by a number of agencies for fiber-optic communication lines installed primarily to support ITS components. Revenue opportunities include the selling of data or services to outside contractors, as well as the use of user fees to provide system funding. These both represent opportunistic situations that occur for a limited number of ITS components. Nevertheless, the opportunity to fund a portion of the O&M costs through these mechanisms should be fully investigated during planning stages.

Finally, the strategy of including ITS procurements as part of larger construction projects has been used by many agencies to lessen the procurement and implementation costs of ITS components. Caution, however, should be applied in utilizing this strategy. While addressing implementation costs, this strategy often overlooks the provision of continuing O&M costs. The contracting requirements for construction projects can result in a contractor being selected who has limited experience in installing or implementing ITS technologies. This procurement strategy should never be followed when the deployment requires specific ITS expertise, such as software development.

6. POTENTIAL PRIVATE SECTOR OPPORTUNITIES

The MAG region has had historical success in attracting private sector interest in providing ITS capabilities. Several initiatives are currently underway by private sector organizations to provide ITS services in the Phoenix region. Several of these ITS initiatives better lend themselves to private-sector development and operation due to the technology or communications required by the improvement. The public sector's involvement in these improvements is primarily limited to a supportive role in the timely provision of data. These private-sector focus initiatives and their current regional and national deployment status are presented in **Table 5**.

Table 5 – Private-Sector Initiatives

ITS Initiative	Deployment Status
▪ In-vehicle mayday systems	▪ Implemented regionally and nationwide
▪ Handheld personal device traveler information systems	▪ Undergoing testing in Phoenix. Implemented in limited national locations.
▪ In-vehicle route guidance systems	▪ Implemented regionally and nationwide
▪ Cable television traveler information systems	▪ Implemented in Tempe and various national locations
▪ Media information service provider	▪ Implemented regionally and nationwide
▪ Commercial vehicle traveler information systems	▪ Undergoing implementation in Arizona. Implemented in limited number of national locations.

Other ITS initiatives are more often better suited to deployment and/or operation by partnerships formed between the public and the private sector. The lead organization, either public or private, is often determined by the specific characteristics of the deployment. While these deployments may be deployed by either the public or private sector without forming partnerships, the opportunity exists for significant benefits through partnering. These public/private partnership opportunities include the initiatives presented in **Table 6**.

Table 6 – Public-Private Partnership Initiatives

ITS Initiative	Deployment Status
▪ Telephone-based traveler information systems	▪ Implemented regionally. Enhancement of regional system currently being developed.
▪ Web-/Internet-based traveler information systems	▪ Implemented regionally and in many other metropolitan regions.
▪ Railroad crossing monitoring systems	▪ None implemented regionally. Undergoing testing in limited national locations.
▪ Parking management systems	▪ Undergoing implementation in Phoenix and Tempe. Deployed in limited national locations
▪ ITS communications provision (e.g., fiber-optic implementation)	▪ Implemented regionally and in many other metropolitan locations

Finally, some ITS initiatives, by their nature, are best suited for implementation by the public sector. For these deployments, the public sector typically takes the lead in the planning and funding of the implementation and operation of the systems. The private sector may play a supporting role as a user of data provided by the system or may provide services to the public sector agency on a contract basis. These public sector initiatives are presented in **Table 7**.

Table 7 – Public-Sector Initiatives

ITS Initiative	Deployment Status
▪ Arterial traffic management systems (e.g., signal coordination)	▪ Implemented regionally and in most other metropolitan regions
▪ Freeway traffic management systems (e.g., ramp metering, variable message signs)	▪ Implemented regionally and in many other metropolitan regions
▪ Advanced public transit systems	▪ Implemented regionally and in many other metropolitan regions
▪ Incident management systems	▪ Implemented regionally and in many other metropolitan regions
▪ Emergency management services	▪ Implemented regionally and in many other metropolitan regions
▪ Commercial vehicle operations	▪ Implemented regionally and in many other metropolitan regions. Enhancement of CVO capabilities currently under development.
▪ Traffic management centers	▪ Implemented regionally and in many other metropolitan regions
▪ Traffic surveillance systems	▪ Implemented regionally and in most other metropolitan regions

While these categories are not intended to be concrete in their designation of public or private roles, they are provided to supply guidance on the appropriate level of public involvement, based on historical deployment characteristics.

7. SUMMARY AND RECOMMENDATIONS

The MAG ITS Committee, in coordination with the AZTech MDI related committees, have a long history of effectively promoting the coordinated implementation of ITS on a regional, multi-jurisdictional basis. While additional opportunities exist to improve the regional implementation of ITS, more significant opportunities exist to improve the operations of ITS in the region. The strategies identified in this report are generally focused on improving the effective coordination ITS operations in the MAG region.

The enhancement of regional collaboration in the implementation and operation of ITS has many potential benefits for the region. Significant opportunities to improve regional cooperation and coordination include:

- **MAG ITS Strategic Plan Update** - The MAG ITS Strategic Plan Update is a regional, collaborative effort and the MAG ITS Committee should facilitate the continued use of the plan. Member jurisdictions should make all efforts to maintain consistency and compatibility with the MAG ITS Strategic Plan Update. This includes ensuring that all ITS elements presented in the plan are properly incorporated into all applicable State, regional, and local transportation plans.
- **Maintaining Consistency with the Regional Architecture** - The *MAG Regional ITS Architecture* provides a framework for improving the compatibility of regional ITS infrastructure and components. ITS implementations and modifications to existing ITS deployments should be consistent with the MAG ITS Regional Architecture.
- **Coordination with the AZTech MDI** - The MAG ITS Committee should continue with efforts to coordinate activities with the AZTech MDI. Additional opportunities for coordination and cooperation between these entities should be encouraged.
- **Shared Operations Agreements** - Opportunities to develop and expand the shared operations of ITS across multiple jurisdictions should be investigated and encouraged. These shared operations have the potential to greatly enhance operational capabilities and improve agency efficiency.
- **Shared Maintenance Agreements** - Jurisdictions should investigate developing joint maintenance agreements to improve the maintenance of ITS equipment and reduce agency costs. The MAG ITS Committee should encourage and facilitate the development of these agreements.

In pursuing these opportunities to enhance regional collaboration in the implementation and operations of ITS, it is critical to properly address issues that may arise between agencies. Several strategies and procedures were identified that will help to minimize any interagency conflicts and aid in addressing these multi-jurisdictional issues when they arise. These strategies include:

- **Identification of Regional Goals for ITS Operations**. - The MAG ITS Committee, with consultation from the ITS Board, should initiate discussions to develop a list of common goals for ITS operation. These goals will provide guidance to member agencies on how ITS will be used to enhance the operations of the regional transportation system. The identification of these goals provides a basis for forming and maintaining sharing agreements between agencies in the region. Agreement among all members is essential to ensure the successful adoption of the regional goals. MAG member agencies should be asked to individually ratify the goals and objectives.
- **Expansion of the Regional Operations Committee** – The MAG ITS Committee should encourage the AZTech Traffic Operations Working Group to assume a broader operational

responsibilities, and integrate with additional jurisdictions and types of systems. This committee would increasingly serve as a forum for improving planning and coordination of regional O&M activities to promote the more efficient use of O&M resources and improved reliability of the ITS deployments. The working Group may also want to consider recruiting additional regional stakeholders to participate in the committee. Potential new members include additional transit representatives, Department of Public Safety, emergency management services, and private-sector organizations such as railroads, commercial vehicle operators, and airport shuttle operators.

- **Formalization of Operating Procedures** - Operating procedures, particularly those for multi-jurisdictional ITS deployments, should be formalized and documented. This will promote the clear understanding of the procedures and ensure they are properly maintained over time.
- **Development of Operations and Maintenance Plans** - The process of developing O&M plans should be enhanced to ensure that the final plans adequately provide sufficient detail to guide the long-term O&M activities. The impact of any deployment on O&M activities should be carefully weighed when designing any ITS implementation or modification to existing ITS. Individual jurisdictions should be encouraged to develop their own internal O&M plans prior to entering into multi-jurisdictional agreements to implement and operate ITS improvements. The MAG ITS Committee should encourage member agencies to enhance their own O&M plans for individual ITS deployments.
- **Enhancement of the Operational Budgeting Procedure** - The budgeting procedures used to plan for operational expenditures should be enhanced to minimize the chance of future funding shortfalls. These budgeting procedures should consider the full costs of ITS operations and maintenance, and also anticipate the impact on O&M expenditures of incremental expansion of the ITS infrastructure.

Regional agencies were surveyed to identify current and future ITS staffing levels, and the adequacy of the available staffing resources. Responding agencies reported an average of 5 full-time staff persons assigned to ITS planning, operations, and maintenance. Two-thirds of the agencies reported that their current staffing level was insufficient to meet the needs of their ITS programs, however. In addition, 90 percent of respondents reported that planned ITS deployments will place even greater demands on agency staffing requirements in the future. In response to this need, agencies reported plans to add an average of 1.7 staff persons to their ITS staffs over the next 5 years – a 34 percent increase in staffing levels.

Estimating the anticipated costs of ITS components can be problematic. The often-significant costs required to operate and maintain ITS components and the relatively short replacement cycles for ITS equipment add complexity to the process of identifying resource requirements of ITS deployments. The accurate estimation of costs, however, is a critical element in the long-term viability of ITS deployments.

Section 4 presents cost estimates that can be used to assist regional planners in predicting capital and O&M costs of ITS elements being considered in the MAG region. The estimates presented in this section include costs to initially deploy the basic infrastructure as well as costs for incrementally expanding the system to include additional roadside components. Both up-front capital cost and continuing O&M cost estimates are provided for use by regional planners.

Many different opportunities exist to reduce the local burden of funding for ITS improvements. The MAG region has done an excellent job at attracting federal funding for regional ITS improvements. Continued federal funding opportunities exist in the form of National Highway System (NHS), Surface Transportation Program (STP), and Congestion Mitigation and Air

Quality Improvement Program (CMAQ) funding. Meanwhile, ITS Discretionary Funding in the form of ITS Integration Program, CVISN, and Corridor Planning and Development and Border Infrastructure program provide opportunities to secure additional ITS targeted funding. In addition to these Federal funding opportunities, several additional options exist for reducing the local burden including:

- Public/private partnerships;
- Resource sharing with public agencies external to the transportation agency; and
- Revenue opportunities.

The MAG region has enjoyed success in attracting private sector investment in providing ITS capabilities. Several initiatives are currently underway by private sector organizations to provide ITS services in the Phoenix region. Some ITS initiatives have historically enjoyed greater success when implemented by the private sector. Other deployments have tended to be better suited to public sector deployment or combined public/private deployment. Section 6 presents a summary of various ITS categories and identifies the typical roles of the public and private sectors.

The operational and implementation strategies presented in this memorandum are intended to assist the MAG ITS Committee in improving the regional deployment and operation of ITS in the Greater Phoenix area. Adoption of these strategies will allow the member agencies to take advantage of opportunities to expand and promote regional collaboration in the implementation and operation of ITS, and help guarantee the long-term viability of the region's ITS infrastructure.

APPENDIX A – DETAILED EQUIPMENT COST INFORMATION

Local cost data for the ITS components under consideration in the MAG region were obtained from the Arizona DOT report: *PECOS – ITI Data Models – Final Report*, June 1998. The cost figures, and anticipated equipment life are shown in **Table A-1**. The structure of these cost figures varies from those presented in the *ITS National Architecture*. In the report, only the local data are presented. This Appendix presents both the local and the national cost estimates for comparison.

Table A-1 – Local Cost Figures Used

Cost Item	Useful Life	Capital Cost	O&M Cost	Total Annual Cost
Variable Message Sign	15	$109,000	$3,500	$10,767
Traffic Surveillance – CCTV	7	$17,000	$2,170	$4,599
Traffic Surveillance – Loops	10	$9,000	$815	$1,715
Weigh-in-Motion	15	$55,000	$5,700	$9,367
Traffic Actuated Ramp Meter	8	$15,000	$3,550	$5,425

The following sheets provide detailed equipment cost information for ITS components planned or under consideration in the MAG region.[1] These cost estimates were compiled using the ITS Deployment Analysis System software. The ITS National Architecture served as the source of the cost information for the equipment unit costs. Definition of the terminology used is presented in **Section 4** of this Technical Memorandum.

These costs represent the average costs experienced for these types of deployments. Users of these cost estimates are encouraged to review the cost assumptions and equipment inventories for the ITS components before applying these costs to any individual planned deployment. Significant cost savings may be realized through the sharing of equipment and integration of deployed components. An analysis of the equipment inventories is also encouraged to help identify cost allocation and funding responsibilities.

The cost estimates for each component are structured to allow the costs to be scaled to any size deployment. Infrastructure costs are accrued for each new technology deployment. Incremental costs are accrued based on the number of deployed elements or units. These units may represent deployment locations (for variable message signs), intersections (for signal coordination), vehicles (for transit AVL), or other appropriate unit depending on the deployed component.

To estimate the total cost of any deployment, the infrastructure and incremental costs are summed, as shown below:

Total Capital Costs = infrastructure capital cost + (# of units * incremental capital cost)

Annual O&M Costs = infrastructure O&M cost + (# of units * incremental O&M cost)

[1] For the purpose of this study, *ITS Components* are defined as combinations of ITS equipment that are meaningful as a deployed system (e.g., CCTV traffic surveillance system). *ITS Equipment* is defined as the individual, non-divisible pieces of equipment (e.g., individual video camera) which are combined to assemble the ITS components.

The annualized costs presented in the spreadsheets represent the amortized costs of deploying the capital equipment and re-deploying the equipment as necessary to replace obsolete equipment. The annualized cost for any individual piece of equipment is estimated as follows:

Annualized Cost = (Capital Cost / Useful Life) + O&M Cost

The following method is used to calculate the total annualized cost of any deployment:

Total Annualized Cost = annualized infrastructure cost + (# of units * annualized incremental cost)

Traffic Actuated Corridor Signal Coordination

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Linked Signal System LAN	20	$ 55,000	$ 1,100	$ 3,850
TOTAL Infrastructure Cost		***$ 55,000***	***$ 1,100***	***$ 3,850***
Incremental Deployment Equipment (Per Intersection)				
Signal Controller Upgrade	20	$ 6,250	$ 350	$ 663
TOTAL Incremental Cost		***$ 6,250***	***$ 350***	***$ 663***

Notes:

Does not include the cost of the traffic signal, or loop detectors.

Central Control Signal Coordination

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Linked Signal System LAN	20	$ 55,000	$ 1,100	$ 3,850
TMC Hardware for Signal Control	5	$ 22,500	$ 2,000	$ 6,500
TMC Software/System Integration	5	$ 200,000	$ -	$ 40,000
TMC Labor	0	$ -	$ 540,000	$ 540,000
TOTAL Infrastructure Cost		***$ 277,500***	***$ 543,100***	***$ 590,350***
Incremental Deployment Equipment (Per Intersection)				
Signal Controller Upgrade	20	$ 6,250	$ 350	$ 663
DS1 Communication Line	20	$ 750	$ 6,600	$ 6,638
TOTAL Incremental Cost		***$ 7,000***	***$ 6,950***	***$ 7,300***

Notes:

Labor costs assume: Operators (2 @ 50% of the time, at $100,000). Maintenance technicians (2 @ $75,000). Transportation Engineer (1 @ 50% of the time, at $100,000). Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.

Update timing plans ($2,000 per system per month for every 10 systems).

Does not include the cost of the traffic signal, or loop detectors.

Emergency Vehicle Signal Priority

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
NA				$ -
TOTAL Infrastructure Cost		***$ -***	***$ -***	***$ -***
Incremental Deployment Equipment				
(Per Intersection)				
Signal Preemption Receiver	5	$ 5,000	$ 125	$ 1,125
Signal Controller Upgrade	20	$ 3,500	$ -	$ 175
Telecommunications (low usage)		$ -	$ 190	$ 190
Subtotal		*$ 8,500*	*$ 315*	*$ 1,490*
(Per Emergency Vehicle)				
Signal Preemption Processor	10	$ 450	$ 10	$ 55
Cell Based Communications Equipment	10	$ 200	$ 10	$ 30
Subtotal		*$ 650*	*$ 20*	*$ 85*
TOTAL Incremental Cost		***$ 9,150***	***$ 335***	***$ 1,575***

Notes:

Does not include the cost of the traffic signal.

Transit Vehicle Signal Priority

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
NA				$ -
TOTAL Infrastructure Cost		***$ -***	***$ -***	***$ -***
Incremental Deployment Equipment				
(Per Intersection)				
Signal Preemption Receiver	5	$ 5,000	$ 125	$ 1,125
Signal Controller Upgrade	20	$ 3,500	$ -	$ 175
Telecommunications (low usage)		$ -	$ 190	$ 190
Subtotal		*$ 8,500*	*$ 315*	*$ 1,490*
(Per Transit Vehicle)				
Signal Preemption Processor	10	$ 450	$ 10	$ 55
Cell Based Communications Equipment	10	$ 200	$ 10	$ 30
Subtotal		*$ 650*	*$ 20*	*$ 85*
TOTAL Incremental Cost		***$ 9,150***	***$ 335***	***$ 1,575***

Notes:

Does not include the cost of the traffic signal.

Arterial Highway Advisory Radio

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
TMC Hardware for Information Disseminatior	5	$ 7,500	$ 375	$ 1,875
TMC Software for Information Dissemination	5	$ 20,000	$ 1,000	$ 5,000
TMC System Integration	20	$ 100,000	$ 5,000	$ 10,000
Labor for Information Dissemination			$ 100,000	$ 100,000
TOTAL Infrastructure Cost		***$ 127,500***	***$ 106,375***	***$ 116,875***
Incremental Deployment Equipment (Per HAR Location)				
DS0 Communication Line	20	$ 750	$ 900	$ 938
HAR Roadside Transceiver	20	$ 24,000	$ 800	$ 2,000
TOTAL Incremental Cost		***$ 24,750***	***$ 1,700***	***$ 2,938***

Notes:

Labor costs assume: One operator. Salary costs are fully loaded and include base salary, overtime, overhead, benefits, etc.

Arterial Variable Message Sign

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
TMC Hardware for Information Disseminatior	5	$ 7,500	$ 375	$ 1,875
TMC Software for Information Dissemination	5	$ 20,000	$ 1,000	$ 5,000
TMC System Integration	20	$ 100,000	$ 5,000	$ 10,000
Labor for Information Dissemination			$ 100,000	$ 100,000
TOTAL Infrastructure Cost		***$ 127,500***	***$ 106,375***	***$ 116,875***
Incremental Deployment Equipment (Per VMS Location)				
DS0 Communication Line	20	$ 750	$ 900	$ 938
Variable Message Sign	20	$ 65,000	$ 4,400	$ 7,650
Variable Message Sign Tower	20	$ 100,000	$ 275	$ 5,275
TOTAL Incremental Cost		***$ 165,750***	***$ 5,575***	***$ 13,863***

Notes:

Labor costs assume: One operator. Salary costs are fully loaded and include base salary, overtime, overhead, benefits, etc.

Pre-set Timing Ramp Metering

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
NA				$ -
TOTAL Infrastructure Cost		***$ -***	***$ -***	***$ -***
Incremental Deployment Equipment (Per Ramp Location)				
Ramp Meter (Signal, Controller)	5	$ 40,000	$ 2,000	$ 10,000
TOTAL Incremental Cost		***$ 40,000***	***$ 2,000***	***$ 10,000***

Notes:

Traffic Actuated Ramp Metering

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
NA				$ -
TOTAL Infrastructure Cost		***$ -***	***$ -***	***$ -***
Incremental Deployment Equipment (Per Ramp Location)				
Ramp Meter (Signal, Controller)	5	$ 40,000	$ 2,000	$ 10,000
Loop Detectors (2)	5	$ 11,000	$ 4,500	$ 6,700
TOTAL Incremental Cost		***$ 51,000***	***$ 6,500***	***$ 16,700***

Notes:

Central Control Ramp Metering

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
TMC Hardware for Freeway Control	5	$ 22,500	$ 2,000	$ 6,500
TMC Software/Integration	5	$ 200,000	$ -	$ 40,000
TMC Labor		$ -	$ 250,000	$ 250,000
TOTAL Infrastructure Cost		***$ 222,500***	***$ 252,000***	***$ 296,500***
Incremental Deployment Equipment (Per Ramp Location)				
Ramp Meter (Signal, Controller)	5	$ 40,000	$ 2,000	$ 10,000
Loop Detectors (2)	5	$ 11,000	$ 4,500	$ 6,700
DS1 Communication Line	20	$ 750	$ 6,600	$ 6,638
TOTAL Incremental Cost		***$ 51,750***	***$ 13,100***	***$ 23,338***

Notes:

Labor costs assume: Operators (2 @ 50% of the time, at $100,000). Maintenance technicians (2 @ $75,000). Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.

Highway Advisory Radio

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
TMC Hardware for Information Dissemination	5	$ 7,500	$ 375	$ 1,875
TMC Software for Information Dissemination	5	$ 20,000	$ 1,000	$ 5,000
TMC System Integration	20	$ 100,000	$ 5,000	$ 10,000
Labor for Information Dissemination			$ 100,000	$ 100,000
TOTAL Infrastructure Cost		***$ 127,500***	***$ 106,375***	***$ 116,875***
Incremental Deployment Equipment (Per HAR Location)				
DS0 Communication Line	20	$ 750	$ 900	$ 938
HAR Roadside Transceiver	20	$ 24,000	$ 800	$ 2,000
TOTAL Incremental Cost		***$ 24,750***	***$ 1,700***	***$ 2,938***

Notes:

Labor costs assume: One operator. Salary costs are fully loaded and include base salary, overtime, overhead, benefits, etc.

Variable Message Sign

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
TMC Hardware for Information Dissemination	5	$ 7,500	$ 375	$ 1,875
TMC Software for Information Dissemination	5	$ 20,000	$ 1,000	$ 5,000
TMC System Integration	20	$ 100,000	$ 5,000	$ 10,000
Labor for Information Dissemination			$ 100,000	$ 100,000
TOTAL Infrastructure Cost		***$ 127,500***	***$ 106,375***	***$ 116,875***
Incremental Deployment Equipment (Per VMS Location)				
DS0 Communication Line	20	$ 750	$ 900	$ 938
Variable Message Sign	20	$ 92,500	$ 4,400	$ 9,025
Variable Message Sign Tower	20	$ 125,000	$ 275	$ 6,525
TOTAL Incremental Cost		***$ 218,250***	***$ 5,575***	***$ 16,488***

Notes:

Labor costs assume: One operator. Salary costs are fully loaded and include base salary, overtime, overhead, benefits, etc.

Fixed Route - Automated Scheduling System

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Transit Center Hardware/Software	10	$ 30,000	$ 600	$ 3,600
Transit Center System Integration	20	$ 362,500	$ -	$ 18,125
Transit Center Labor		$ -	$ 150,000	$ 150,000
DS3 Communication Line	20	$ 4,000	$ 24,000	$ 24,200
TOTAL Infrastructure Cost		***$ 396,500***	***$ 174,600***	***$ 195,925***
Incremental Deployment Equipment (Per Transit Vehicle)				
Driver Interface and Schedule Processor	10	$ 400	$ 10	$ 50
Cell-Based Communications	10	$ 200	$ 10	$ 30
Wireless Communications (Medium Usage)		$ -	$ 650	$ 650
TOTAL Incremental Cost		***$ 600***	***$ 670***	***$ 730***

Notes:

Labor costs assume: 2 staff @ $75,000 each average. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.

Fixed Route - Automatic Vehicle Location

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Transit Center Hardware/Software	10	$ 35,000	$ 600	$ 4,100
Transit Center System Integration	20	$ 300,000	$ -	$ 15,000
Transit Center Labor		$ -	$ 150,000	$ 150,000
DS3 Communication Line	20	$ 4,000	$ 24,000	$ 24,200
Vehicle Location Interface	20	$ 12,500	$ -	$ 625
TOTAL Infrastructure Cost		***$ 351,500***	***$ 174,600***	***$ 193,925***
Incremental Deployment Equipment (Per Transit Vehicle)				
Driver Interface and Schedule Processor	10	$ 400	$ 10	$ 50
Cell-Based Communications	10	$ 200	$ 10	$ 30
GPS/DGPS	10	$ 650	$ 15	$ 80
Trip Computer and Processor	10	$ 125	$ 10	$ 23
Wireless Communications (High Usage)		$ -	$ 1,500	$ 1,500
TOTAL Incremental Cost		***$ 1,375***	***$ 1,545***	***$ 1,683***

Notes:

Labor costs assume: 2 staff @ $75,000 each average. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.

Fixed Route - Security System

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Video Monitors for Security System (5)	10	$ 17,500	$ 875	$ 2,625
Hardware for Security System	10	$ 72,500	$ 1,450	$ 8,700
System Integration of Security System	20	$ 375,000	$ -	$ 18,750
Labor for Security System		$ -	$ 224,500	$ 224,500
Emergency Response Hardware	10	$ 22,500	$ 450	$ 2,700
Emergency Response Software	10	$ 110,000	$ 2,000	$ 13,000
DS0 Communication Line	20	$ 750	$ 900	$ 938
TOTAL Infrastructure Cost		***$ 598,250***	***$ 230,175***	***$ 271,213***
Incremental Deployment Equipment				
(Per Transit Vehicle)				
Driver Interface and Schedule Processor	10	$ 400	$ 10	$ 50
Cell Based Communication Equipment	10	$ 200	$ 10	$ 30
Security Package (CCTV, Hot Button)	10	$ 4,750	$ 240	$ 715
Wireless Communications, Low Usage1		$ -	$ 190	$ 190
Subtotal		*$ 5,350*	*$ 450*	*$ 985*
(Per Remote Location)				
CCTV Camera	10	$ 4,500	$ 90	$ 540
Integration of Camera w/ Existing Systems	10	$ 2,250	$ -	$ 225
DS1 Communication Line	20	$ 750	$ 6,600	$ 6,638
Subtotal		*$ 7,500*	*$ 6,690*	*$ 7,403*
TOTAL Incremental Cost		***$ 12,850***	***$ 7,140***	***$ 8,388***

Notes:

Labor costs assume: 3 staff @ $75,000 each average. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.

Paratransit - Automated Scheduling System

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Transit Center Hardware/Software	10	$ 22,500	$ 600	$ 2,850
Transit Center System Integration	20	$ 362,500	$ -	$ 18,125
Transit Center Labor		$ -	$ 150,000	$ 150,000
DS3 Communication Line	20	$ 4,000	$ 24,000	$ 24,200
TOTAL Infrastructure Cost		***$ 389,000***	***$ 174,600***	***$ 195,175***
Incremental Deployment Equipment (Per Transit Vehicle)				
Driver Interface and Schedule Processor	10	$ 400	$ 10	$ 50
Cell-Based Communications	10	$ 200	$ 10	$ 30
Wireless Communications (Medium Usage)		$ -	$ 650	$ 650
TOTAL Incremental Cost		***$ 600***	***$ 670***	***$ 730***

Notes:

Labor costs assume: 2 staff @ $75,000 each average. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.

Paratransit - Automatic Vehicle Location

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Transit Center Hardware/Software	10	$ 35,000	$ 600	$ 4,100
Transit Center System Integration	20	$ 300,000	$ -	$ 15,000
Transit Center Labor		$ -	$ 150,000	$ 150,000
DS3 Communication Line	20	$ 4,000	$ 24,000	$ 24,200
Vehicle Location Interface	20	$ 12,500	$ -	$ 625
TOTAL Infrastructure Cost		***$ 351,500***	***$ 174,600***	***$ 193,925***
Incremental Deployment Equipment (Per Transit Vehicle)				
Driver Interface and Schedule Processor	10	$ 400	$ 10	$ 50
Cell-Based Communications	10	$ 200	$ 10	$ 30
GPS/DGPS	10	$ 650	$ 15	$ 80
Trip Computer and Processor	10	$ 125	$ 10	$ 23
Wireless Communications (High Usage)		$ -	$ 1,500	$ 1,500
TOTAL Incremental Cost		***$ 1,375***	***$ 1,545***	***$ 1,683***

Notes:

Labor costs assume: 2 staff @ $75,000 each average. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.

Electronic Transit Fare Payment

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Transit Center Hardware	10	$ 30,000	$ 600	$ 3,600
Transit Center Software, Integration	20	$ 815,000	$ 9,000	$ 49,750
Transit Center Labor		$ -	$ 150,000	$ 150,000
Further Software Upgrade for Electronic Fare	20	$ 50,000	$ 1,000	$ 3,500
DS0 Communication Line (56Kbps capacity)	20	$ 750	$ 900	$ 938
DS1 Communication Line (1.544Mbps capac	20	$ 750	$ 6,600	$ 6,638
TOTAL Infrastructure Cost		***$ 896,500***	***$ 168,100***	***$ 214,425***
Incremental Deployment Equipment				
(Per Transit Vehicle)				
Driver Interface and Processor	10	$ 400	$ 10	$ 50
Cell Based Communication Equipment	10	$ 200	$ 10	$ 30
Electronic Farebox	10	$ 1,150	$ 50	$ 165
Wireless Communications (High Usage)	20	$ 750	$ 1,500	$ 1,538
Subtotal		*$ 2,500*	*$ 1,570*	*$ 1,783*
(Per Remote Location)				
Smart Card Vending Machine	50	$ 38,500	$ 1,925	$ 2,695
Software/Integration for Smart Card Vending	20	$ 4,000	$ -	$ 200
DS1 Communication Line	20	$ 750	$ 6,600	$ 6,638
Subtotal		*$ 43,250*	*$ 8,525*	*$ 9,533*
TOTAL Incremental Cost		***$ 45,750***	***$ 10,095***	***$ 11,315***

Notes:

Labor costs assume: 2 staff @ $75,000 each average. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.

Incident Detection/Verification

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Video Monitors/Wall for Incident Detection	5	$ 45,000	$ 2,250	$ 11,250
TMC Incident Detection Hardware	5	$ 100,500	$ 5,025	$ 25,125
TMC System Integration	20	$ 100,000	$ 5,000	$ 10,000
TMC Incident Detection Software	5	$ 100,000	$ 5,000	$ 25,000
TMC Labor		$ -	$ 150,000	$ 150,000
TOTAL Infrastructure Cost		***$ 345,500***	***$ 167,275***	***$ 221,375***
Incremental Deployment Equipment				
NA				$ -
TOTAL Incremental Cost		***$ -***	***$ -***	***$ -***

Notes:

Does not include the cost of traffic surveillance.

Labor costs assume: 2 operators @ $75,000. Salary costs are fully loaded and include base salary, overtime, overhead, benefits, etc.

Incident Response/Management

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Video Monitors/Wall for Incident Detection	5	$ 3,000	$ 150	$ 750
TMC Incident Response Hardware	5	$ 3,000	$ 150	$ 750
TMC System Integration	20	$ 200,000	$ -	$ 10,000
TMC Incident Response Software	2	$ 15,000	$ 750	$ 8,250
TMC Labor		$ -	$ 112,500	$ 112,500
Emergency Management Center Hardware	10	$ 22,500	$ 450	$ 2,700
Emergency Management Center Software	10	$ 110,000	$ 2,000	$ 13,000
Emergency Response Labor		$ -	$ 112,500	$ 112,500
DS0 Communication Line	20	$ 750	$ 900	$ 938
TOTAL Infrastructure Cost		***$ 354,250***	***$ 229,400***	***$ 261,388***
Incremental Deployment Equipment				
NA				$ -
TOTAL Incremental Cost		***$ -***	***$ -***	***$ -***

Notes:

Does not include the cost of emergency response vehicles.

Labor costs assume: 3 operators @ $75,000. Salary costs are fully loaded and include base salary, overtime, overhead, benefits, etc.

Emergency Vehicle Control Service

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Emergency Management Center Hardware	10	$ 22,500	$ 450	$ 2,700
Emergency Management Center Software	10	$ 110,000	$ 2,000	$ 13,000
Emergency Response Labor		$ -	$ 150,000	$ 150,000
Emergency Communications Software	20	$ 7,500	$ 3,750	$ 4,125
DS0 Communications Line	20	$ 750	$ 900	$ 938
DS1 Communications Line	20	$ 1,500	$ 6,600	$ 6,675
Systems Integration	20	$ 100,000	$ 1,250	$ 6,250
Map Database Software	2	$ 22,500	$ -	$ 11,250
Software for Route Guidance	20	$ 250,000	$ 1,500	$ 14,000
Database Upgrade for Route Guidance	2	$ 150,000	$ -	$ 75,000
Hardware for Emergency Route Planning	5	$ 15,000	$ 400	$ 3,400
Software for Emergency Route Planning	20	$ 50,000	$ 1,200	$ 3,700
Added Labor for Interactive Information		$ -	$ 75,000	$ 75,000
TOTAL Infrastructure Cost		***$ 729,750***	***$ 243,050***	***$ 366,038***
Incremental Deployment Equipment (Per Emergency Vehicle)				
Communications Interface	10	$ 1,150	$ 10	$ 125
Wireless Communications		$ -	$ 190	$ 190
TOTAL Incremental Cost		***$ 1,150***	***$ 200***	***$ 315***

Notes:

Does not include the cost of emergency response vehicles.

Labor costs assume: 3 operators @ $75,000. Salary costs are fully loaded and include base salary, overtime, overhead, benefits, etc.

Emergency Vehicle Automatic Vehicle Location

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Emergency Management Center Hardware	10	$ 16,000	$ 200	$ 1,800
Emergency Management Center Software	10	$ 110,000	$ 2,000	$ 13,000
Emergency Response Labor		$ -	$ 100,000	$ 100,000
Emergency Communications Software	20	$ 7,500	$ 3,750	$ 4,125
TOTAL Infrastructure Cost		***$ 133,500***	***$ 105,950***	***$ 118,925***
Incremental Deployment Equipment (Per Emergency Vehicle)				
Communication Equipment	7	$ 700	$ 15	$ 115
Wireless Communications		$ -	$ 190	$ 190
GPS/DGPS	7	$ 650	$ 25	$ 118
TOTAL Incremental Cost		***$ 1,350***	***$ 230***	***$ 423***

Notes:

Does not include the cost of emergency response vehicles.

Labor costs assume: 1 operator @ $75,000 and .5 technichian @ $50,000. Salary costs are fully loaded and include base salary, overtime, overhead, benefits, etc.

Telephone-Based Traveler Information System

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
TMC Information Dissemination Hardware	5	$ 7,500	$ 375	$ 1,875
TMC Information Dissemination Software	5	$ 20,000	$ 1,000	$ 5,000
TMC System Integration	20	$ 100,000	$ 5,000	$ 10,000
Labor for Traffic Information Dissemination		$ -	$ 100,000	$ 100,000
DS3 Communication Line	20	$ 4,000	$ 48,000	$ 48,200
Transit Center Hardware	10	$ 22,500	$ -	$ 2,250
Transit Center Software, Integration	20	$ 815,000	$ 9,000	$ 49,750
Transit Center Labor		$ -	$ 150,000	$ 150,000
DS3 Communication Line	20	$ 4,000	$ 48,000	$ 48,200
Information Service Center Hardware	20	$ 45,000	$ 900	$ 3,150
Info Center System Integration	5	$ 100,000	$ -	$ 20,000
Information Service Center Software	20	$ 275,000	$ 20,625	$ 34,375
Map Database Software	2	$ 22,500	$ -	$ 11,250
Information Service Center Labor		$ -	$ 225,000	$ 225,000
TOTAL Infrastructure Cost		***$ 1,415,500***	***$ 607,900***	***$ 709,050***
Incremental Deployment Equipment (Per Intersection)				
NA				$ -
TOTAL Incremental Cost		***$ -***	***$ -***	***$ -***

Notes:

Does not include the cost of traffic surveillance or data collection.

Web/Internet-Based Traveler Information System

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
TMC Information Dissemination Hardware	5	$ 7,500	$ 375	$ 1,875
TMC Information Dissemination Software	5	$ 20,000	$ 1,000	$ 5,000
TMC System Integration	20	$ 100,000	$ 5,000	$ 10,000
Labor for Traffic Information Dissemination		$ -	$ 100,000	$ 100,000
DS3 Communication Line	20	$ 4,000	$ 48,000	$ 48,200
Transit Center Hardware	10	$ 22,500	$ -	$ 2,250
Transit Center Software/Integration	20	$ 815,000	$ 9,000	$ 49,750
Transit Center Labor		$ -	$ 150,000	$ 150,000
DS3 Communication Line	20	$ 4,000	$ 48,000	$ 48,200
Information Service Center Hardware	20	$ 45,000	$ 900	$ 3,150
Info Center System Integration	5	$ 100,000	$ -	$ 20,000
Information Service Center Software	20	$ 412,000	$ 20,625	$ 41,225
Map Database Software	2	$ 22,500	$ -	$ 11,250
Information Service Center Labor		$ -	$ 225,000	$ 225,000
TOTAL Infrastructure Cost		***$ 1,552,500***	***$ 607,900***	***$ 715,900***
Incremental Deployment Equipment (Per Intersection)				
NA				$ -
TOTAL Incremental Cost		***$ -***	***$ -***	***$ -***

Notes:

Does not include the cost of traffic surveillance or data collection.

Kiosk-Based Traveler Information System

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
TMC Information Dissemination Hardware	5	$ 7,500	$ 375	$ 1,875
TMC Information Dissemination Software	5	$ 20,000	$ 1,000	$ 5,000
TMC System Integration	20	$ 100,000	$ 5,000	$ 10,000
Labor for Traffic Information Dissemination		$ -	$ 100,000	$ 100,000
DS3 Communication Line	20	$ 4,000	$ 48,000	$ 48,200
Transit Center Hardware	10	$ 22,500	$ -	$ 2,250
Transit Center Software/Integration	20	$ 815,000	$ 9,000	$ 49,750
Transit Center Labor		$ -	$ 150,000	$ 150,000
DS3 Communication Line	20	$ 4,000	$ 48,000	$ 48,200
Information Service Center Hardware	20	$ 45,000	$ 900	$ 3,150
Info Center System Integration	5	$ 100,000	$ -	$ 20,000
Information Service Center Software	20	$ 412,000	$ 20,625	$ 41,225
Map Database Software	2	$ 22,500	$ -	$ 11,250
Information Service Center Labor		$ -	$ 225,000	$ 225,000
TOTAL Infrastructure Cost		***$ 1,552,500***	***$ 607,900***	***$ 715,900***
Incremental Deployment Equipment (Per Kiosk Location)				
Informational Kiosk	7	$ 35,000	$ 4,500	$ 9,500
Informational Kiosk Integration w/ System	7	$ 11,000	$ -	$ 1,571
TOTAL Incremental Cost		***$ 46,000***	***$ 4,500***	***$ 11,071***

Notes:

Does not include the cost of traffic surveillance or data collection.

Weigh-in-Motion

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
NA				$ -
TOTAL Infrastructure Cost		***$ -***	***$ -***	***$ -***
Incremental Deployment Equipment				
(Per Roadside Inspection Facility)				
Weigh-in-Motion Facility	10	$ 71,500	$ 3,500	$ 10,650
Wireline to WIM Facility	10	$ 1,500	$ 150	$ 300
TOTAL Incremental Cost		***$ 73,000***	***$ 3,650***	***$ 10,950***

Notes:

Represents the incremantal cost of adding WIM to an existing CVO inspection facility

Safety Information Exchange

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Commercial Vehicle Admin Hardware	10	$ 22,500	$ 450	$ 10,950
CV Admin Software/Integration	20	$ 210,000	$ 4,200	$ 4,200
CV Admin Labor		$ -	$ 300,000	$ 301,500
Software for Inter-Agency Info Exchange	20	$ 30,000	$ 600	$ 600
Labor for Inter-Agency Info Exchange		$ -	$ 74,500	$ 77,500
Software Upgrade for Safety Administration	20	$ 60,000	$ 1,200	$ 1,238
DS1 Communication Line	20	$ 750	$ 6,600	$ 6,600
TOTAL Infrastructure Cost		***$ 300,750***	***$ 387,550***	***$ 402,588***
Incremental Deployment Equipment (Per Inspection Facility)				
Check Station Structure	20	$ 62,500	$ -	$ 3,125
Signal Board	10	$ 12,500	$ 1,250	$ 2,500
Signal Indicator	20	$ 7,500	$ 375	$ 750
Check Station Software, Integration	20	$ 197,500	$ 3,950	$ 13,825
Check Station Hardware	10	$ 22,500	$ -	$ 2,250
DS0 Communication Line	20	$ 750	$ 900	$ 938
TOTAL Incremental Cost		***$ 303,250***	***$ 6,475***	***$ 23,388***

Notes:

Represents the incremental cost of adding the component to an existing CVO inspection facility

Traffic Management Center

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Basic Facilities/Communication	30	$ 4,000,000	$ 500,000	$ 633,333
TOTAL Infrastructure Cost		***$ 4,000,000***	***$ 500,000***	***$ 633,333***
Incremental Deployment Equipment (Per Intersection)				
NA				$ -
TOTAL Incremental Cost		***$ -***	***$ -***	***$ -***

Notes:

Cost are scaled to deployment in a large region (population >750,000).

Costs for a mid-sized region (population 250,000 - 750,000) would average $3,200,000 (capital) $440,000 (O&M).

Costs for a small region (population < 250,000) would average $2,800,000 (capital) $410,000 (O&M).

Traffic Surveillance - CCTV

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Hardware/Software for Traffic Surveillance	20	$ 150,000	$ 7,500	$ 15,000
System Integration	20	$ 250,000	$ 12,500	$ 25,000
TOTAL Infrastructure Cost		***$ 400,000***	***$ 20,000***	***$ 40,000***
Incremental Deployment Equipment (Per Intersection)				
Video Camera	10	$ 37,500	$ 1,150	$ 4,900
Camera Tower	20	$ 34,000	$ 475	$ 2,175
DS3 Communication Line	20	$ 4,000	$ 48,000	$ 48,200
TOTAL Incremental Cost		***$ 75,500***	***$ 49,625***	***$ 55,275***

Notes:

Traffic Surveilance - Loop Detectors

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Hardware/Software for Traffic Surveillance	20	$ 150,000	$ 7,500	$ 15,000
System Integration	20	$ 250,000	$ 12,500	$ 25,000
TOTAL Infrastructure Cost		***$ 400,000***	***$ 20,000***	***$ 40,000***
Incremental Deployment Equipment (Per Intersection)				
Loop Detector (double set)	5	$ 5,500	$ 2,250	$ 3,350
DS3 Communication Line	20	$ 4,000	$ 48,000	$ 48,200
TOTAL Incremental Cost		***$ 9,500***	***$ 50,250***	***$ 51,550***

Notes:

Parking Management Systems

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Information Dissemination Hardware	5	$ 7,500	$ 375	$ 1,875
Information Dissemination Software	5	$ 20,000	$ 1,000	$ 5,000
Information Systems Integration	20	$ 100,000	$ 5,000	$ 10,000
Information Dissemination Labor		$ -	$ 100,000	$ 100,000
Traffic Surveillance Hardware/Software	20	$ 150,000	$ 7,500	$ 15,000
System Integration	20	$ 250,000	$ 12,500	$ 25,000
TOTAL Infrastructure Cost		***$ 527,500***	***$ 126,375***	***$ 156,875***
Incremental Deployment Equipment (Per Location)				
Variable Message Sign	20	$ 100,000	$ 5,000	$ 10,000
Variable Message Sign Tower	20	$ 125,000	$ -	$ 6,250
DS0 Communication Line	20	$ 750	$ 900	$ 938
DS1 Communication Line	20	$ 750	$ 6,600	$ 6,638
Video Camera	10	$ 40,000	$ 800	$ 4,800
Video Camera Tower	20	$ 40,000	$ -	$ 2,000
DS3 Communication Line	20	$ 4,000	$ 12,000	$ 12,200
TOTAL Incremental Cost		***$ 310,500***	***$ 25,300***	***$ 42,825***

Notes:

Railroad Crossing Monitoring System

Equipment	Useful Life	Capital Cost	O&M Cost	Annualized Cost
Basic Infrastructure Equipment				
Software for Rail Crossing Monitor	5	$ 20,000	$ 2,000	$ 6,000
Integration for Rail Crossing Monitor	20	$ 100,000	$ -	$ 5,000
Labor for Rail Crossing Monitor		$ -	$ 50,000	$ 50,000
TOTAL Infrastructure Cost		***$ 120,000***	***$ 52,000***	***$ 61,000***
Incremental Deployment Equipment (Per Location)				
Rail Crossing 4-Quad Gate, Signals	20	$ 122,500	$ 4,550	$ 10,675
Rail Crossing Train Detector	20	$ 18,750	$ 1,000	$ 1,938
Rail Crossing Controller	10	$ 9,000	$ 4,500	$ 5,400
Rail Crossing Pedestrian Warning Signal	20	$ 12,500	$ 2,500	$ 3,125
Rail Crossing Trapped Vehicle Detector	10	$ 27,500	$ 1,375	$ 4,125
Loop Detectors (Double Set)	5	$ 6,500	$ 650	$ 1,950
DS1 Communication Line	20	$ 750	$ 6,600	$ 6,638
TOTAL Incremental Cost		***$ 197,500***	***$ 21,175***	***$ 33,850***

Notes: